# HOLDING THE EDGE





## SUMMARY



UNITED STATES CONGRESS OTA
CONGRESS OF THE UNITED STATES OFFICE OF TECHNOLOGY ASSESSMENT

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# EDGE

## Maintaining the Defense Technology Base

## SUMMARY

CONGRESS OF THE UNITED STATES   OFFICE OF TECHNOLOGY ASSESSMENT

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# Foreword

Technological superiority has been a cornerstone of United States security and industry since World War II. That cornerstone is not crumbling, but over the past decade it has weathered significantly. Foreign companies have made deep inroads into high-technology markets that had been more or less the exclusive domain of U.S. industry. In addition to causing economic problems, this has fostered dependence on foreign sources for defense equipment at a time when the technology in defense systems comes increasingly from the civilian sector. At the same time, the Department of Defense reports that Soviet defense technology is catching up with ours, and sophisticated Western military equipment is routinely sold to third world nations.

These trends—and others—have prompted the Senate Committee on Armed Services to ask what needs to be done to maintain the base of high technology on which U.S. national security depends. This report, the second of OTA's assessment "Maintaining the Defense Technology Base," looks into that question in some depth. An earlier report, *The Defense Technology Base: Introduction and Overview* (OTA-ISC-374, March 1988), provided a broad view of the defense technology base and the concerns regarding its health.

This report develops some of the ideas introduced in the first report. It examines the management of DoD technology base programs and laboratories. It also analyzes the process through which technology is introduced into defense systems, in order to understand why it takes so long and what might be done to speed the process up. Finally, this report examines the exploitation of civilian commercial sector technology for defense needs. It concentrates on the dual questions of expediting military access to civilian technology and keeping the necessary base of technology alive and well in the United States. Volume 2 of this report contains extensive appendices and will be published in the summer of 1989.

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John H. Gibbons

JOHN H. GIBBONS
*Director*

# Defense Technology Base Advisory Panel

Walter B. Laberge, *Chair*
Vice President of Corporate Development
Lockheed Corp.

Michael R. Bonsignore
President
Honeywell International

William Carey
Consultant to the President
Carnegie Corp. of New York

Thomas E. Cooper
Vice President
Aerospace Technology
General Electric

John Deutch
Provost
Massachusetts Institute of Technology

Robert Fossum
Dean
School of Engineering and Applied Sciences
Southern Methodist University

Jacques Gansler
Senior Vice President
The Analytic Sciences Corp.

B.R. Inman
Admiral, USN (retired)
Chairman and Chief Executive Officer
Westmark Systems, Inc.

Paul Kaminski
President
H&Q Technology Partners, Inc.

Lawrence Korb
Director
The Center for Public Policy
Brookings Institution

George Kozmetsky
Executive Associate—Economic Affairs
University of Texas System
University of Texas, Austin

Ray L. Leadabrand
President
Leadabrand & Assoc.

Jan Lodal
President
INTELUS

Edward C. Meyer
General, USA (retired)

Robert R. Monroe
Vice Admiral, USN (retired)
Senior Vice President & Manager, Defense & Space
Bechtel National, Inc.

William J. Perry (ex officio)
Managing Partner
H&Q Technology Partners, Inc.

Richard Pew
Principal Scientist
BBN Laboratories, Inc.

Herman Postma
Senior Vice President
Martin Marietta Energy Systems, Inc.

Judith Reppy
Associate Director
Cornell Peace Studies Program

Richard Samuels
Professor
Department of Political Science
Massachusetts Institute of Technology

John P. Shebell
Manager, RAMP Engineering
Customer Service Systems Engineering
Digital Equipment Corp.

Michael Thompson
Executive Director
Integrated Circuit Design Division
AT&T Bell Laboratories

S.L. Zeiberg
Vice President Technical Operations
Martin Marietta Electronics and Missiles Group

NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

# OTA Project Staff—Defense Technology Base

Lionel S. Johns, *Assistant Director, OTA*
*Energy, Materials, and International Security Division*

Peter Sharfman, *International Security and Commerce Program Manager* (through February 1989)

Alan Shaw, *International Security and Commerce Program Manager* (from March 1989)

**Alan Shaw**, *Project Director*

William W. Keller

Gerald L. Epstein

Laurie Evans Gavrin[1]

Christine Condon[2]

**Congressional Research Service Contributor**

Michael E. Davey

**Administrative Staff**

Jannie Horne (through November 1988)

Cecile Parker

Jackie Robinson

Louise Staley

**Contractors**

P. Robert Calaway

Arnold Levine

MIT/Japan Science and Technology Program

[1]On assignment from OTA's Energy and Materials Program.
[2]On assignment from the Department of Defense.

## Workshop on the Relationship Between Military & Civilian Fiber Optics

John R. Whinnery, *Chair*
University Professor Emeritus
Department of Electrical Engineering and Computer Sciences
University of California, Berkeley

James H. Davis
Director, Fiber Optics Program Office
Naval Sea Systems Command

Brian Hendrickson
Chief
Electro-Optics Technology Branch
U.S. Air Force

Raymond E. Jaeger
President and CEO
SpecTran Corp.

Donald B. Keck
Director
Applied Physics Research & Development Laboratories
Corning Glass Works

Tingye Li
Department Head
Light Wave Systems Research Department
AT&T Bell Laboratories

John W. Lyons
Director
National Engineering Laboratory
National Institute of Standards and Technology

Alan McAdams
Professor
Johnson Graduate School of Management
Cornell University

William C. McCorkle
Technical Director
U.S. Army Missile Command—Redstone Arsenal

Kenneth Nill
Executive Vice President
Lasertron

Paul Polishuk
President and Chairman
Information Gatekeepers Group of Companies

Jan H. Suwinski
Senior Vice President and General Manager
Telecommunications
Corning Glass Works

Robert W. Tarwater
Light Guide Fiber & Cable Manager
AT&T Network Systems

## Workshop on the Relationship Between Military & Civilian Software

Larry E. Druffel, *Chair*
Director
Software Engineering Institute
Carnegie-Mellon University

Victor R. Basili
Professor
Department of Computer Sciences
University of Maryland, College Park

Barry Boehm
Chief Scientist
TRW, Inc.

Elaine Bond
Senior Vice President
The Chase Manhattan Bank

Mike Devlin
Executive Vice President
Rational

Jeffrey M. Heller
Senior Vice President
Electronic Data Systems

Dana P. Lajoie
Technical Director
Government Systems Group
Digital Equipment Corp.

John A. Lytle
Director of Technical Development
Planning Research Corp.

Allan L. Scherr
Vice President, Development & Integration
Applications Systems Division
IBM

Mike Weidemer
Deputy Director
Mission Critical Computer Engineering
Air Force Systems Command

David M. Weiss
Principal Member—Technical Staff
Software Productivity Consortium

## Workshop on the Relationship Between Military & Civilian PMCs

Dick J. Wilkins, *Chair*
Director
Center for Composite Materials
University of Delaware, Newark

Ric Abbott
Principal Engineer
Advanced Composites Project
Beech Aircraft Corp.

James N. Burns
Vice President of Marketing
Hercules, Inc.

Samuel J. Dastin
Director, Advanced Materials
Grumman Aircraft Systems

Bernard M. Halpin, Jr.
Manager, Composites Development Branch
Materials Technology Laboratory
U.S. Army Laboratory Command

James J. Kelly
Program Area Manager
Materials
Office of Naval Technology

Robert Manildi
Manager, Advanced Composites
Hexcel Corp.

Michael J. Michno
Director of Technology
Advanced Composites
Amoco
Performance Products

Alan G. Miller
Unit Chief, Chemical Technology
Boeing Commercial Aircraft

Thomas F. O'Brien
Segment Manager
Advanced Composites Division
Dupont Co.

Frances Rensvold
Physical Science Administrator
Aero Mechanics Technology, Andrews Air Force Base

Douglas C. Ruhmann
Chief Design Engineer
Manager, Materials & Processes
McDonnell Douglas Astronautics Co.

Nick Spenser
Sales Manager
Composites Materials
CIBA-GEIGY

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## INTRODUCTION

Not long ago, the United States was the undisputed technological leader of the world. U.S. military equipment was meaningfully and undeniably more sophisticated than that of the Soviet Union, and our allies sought American technology for their own defense efforts. American companies developed and sold high-technology products to a world that could not produce them competitively. Defense-related developments led American technology and often "spun-off" into the civilian sector, creating products and whole industries. This reinforced a U.S. defense posture based on using technological superiority to offset whatever advantages the Soviet Union and other potential adversaries might have.

As we approach the 21st century, much has changed. The model of U.S. technology leading the world, with defense technology leading the United States, still retains some validity. But it is a diminishingly accurate image of reality. Soviet defense technology increasingly approaches our own, and sophisticated weapons appear in the hands of third world nations not long after their introduction into Western and Soviet arsenals. At the same time, the U.S. military has been plagued with complex systems that do not work as expected, work only after expensive fixes, or simply do not work. Most are high-priced and take a long time to develop. Increasingly, leading edge technology comes from an internationalized, civilian-oriented economy, which puts a premium on exploiting technology as well as developing it.

As a result, the Nation faces a complex set of interrelated problems that bear on its ability to continue to develop and manufacture in sufficient quantity the technologically advanced materiel on which we base our national security posture. There are specific concerns about: 1) the continued ability of the Department of Defense (DoD) and its contractors to develop the technologies it needs; 2) the ability of DoD and the defense industries to turn these technologies into useful, affordable products in a timely fashion; and 3) the ability of DoD to exploit the technology that is being developed worldwide in the private civil sector.

Concern over the availability of the latest technology for defense applications, and the ability of U.S. industry to engineer and produce equipment based on that technology rapidly and affordably, led the Senate Armed Services Committee to request that OTA undertake an assessment of the defense technology base. This is a summary of the second report of that assessment. The previous report, *The Defense Technology Base: Introduction and Overview*,[1] described what the defense technology base is and presented the major problems facing the Nation. This report looks in depth into some of the issues raised in the previous report. It identifies strengths and weaknesses of the U.S. defense technology base and analyzes options for enhancing the strengths and remedying the weaknesses.

This summary is divided into five sections. The first section is an introduction to the topic. The second section outlines options for Congress. The third addresses the strategic management of DoD technology base programs. It examines the system by which the goals of the technology base programs are identified as well as the methods used to allocate resources in order to reach those goals. The emphasis there is on the role played by the Office of the Secretary of Defense (OSD) in guiding and coordinating the efforts of the Army, Navy, Air Force, and other DoD elements. The third section also addresses the management of the laboratories run by the three Services. The

[1]U.S. Congress, Office of Technology Assessment, *The Defense Technology Base: Introduction and Overview—A Special Report*, OTA-ISC-374 (Washington, DC: U.S. Government Printing Office, March 1988).

fourth section analyzes delays in getting technology into the field. The final section is concerned with "dual use" technology, i.e., technology used in both the civilian and defense sectors.

A large part of the technology that ultimately winds up in weapons and other defense systems is either developed or directly sponsored by DoD. This is particularly true of technology that is altogether new, makes a major difference in the performance of defense equipment, and is of little interest to commercial industry. How DoD runs its technology base programs is therefore of major importance. In recent years DoD has spent roughly $9 billion per year on its technology base programs: research (budget category 6.1), exploratory development (6.2), and advanced technology demonstration (6.3A). Roughly 40 percent of this is spent by the three Service departments (Army, Navy, and Air Force). Another 14 percent is controlled by the Defense Advanced Research Projects Agency (DARPA, formerly ARPA). Another 39 percent finances the Strategic Defense Initiative Organization (SDIO).[2] Although all of SDIO's funds are allocated in the 6.3A budget category, according to SDIO only about 15 to 20 percent is actually spent on technology base activities.

The three Services run their technology base programs and their R&D institutions differently.[3] Some of this is the result of recent planning, while much of it results from organizational "cultures" developed over many years. The Army's effort emphasizes decentralization. The Army runs some relatively small research laboratories which focus on selected topics, while larger research, development, and engineering centers are closely tied to "buying commands."[4] The Navy stresses in-house research and development both in the Naval Research Laboratory, a broad-based corporate lab that serves and underpins the Navy's entire technology effort, and in full-spectrum research and development (R&D) centers that nurture ideas from basic research through preproduction stages. These centers have traditional ties to the equipment needs of various functional parts of the operational Navy, but are not formally tied to specific buying commands. The Air Force, which contracts out more of its R&D effort than either of the other Services, centralizes its efforts within the Air Force Systems Command. Its technology base programs are seen as a link between buying commands (the divisions of Systems Command) and the defense industry. The basic theme is to buy technology and make sure it gets to industry. The Air Force has recently adopted the position that technology base programs should be a "corporate investment" funded at some fixed fraction of the budget. The Air Force puts a greater emphasis on R&D-related career paths than do the other Services.

With such diversity (including that added by DARPA, the other defense agencies and SDIO), if the program is to have overall planning and coordination—and not everyone agrees that it should—leadership almost has to come from the Office of the Secretary of Defense.

Actual R&D is performed primarily by industry, universities, and the laboratories run by the Services.[5] In most cases laboratory is a misnomer, although a convenient shorthand. These latter institutions, as a group, perform technology base work in addition to advanced and even full-scale development. They also

[2]Other defense agencies account for approximately 7 percent of DoD technology base program funding. (See footnote 1, p. 19 of this report.)

[3]All three, however, orient their programs heavily toward current product areas. Nontraditional ideas do not fit well into the system.

[4]A buying command is one of a number of organizations within the Armed Services responsible for developing and buying military equipment and systems.

[5]Work is also done by other government laboratories (e.g., the Department of Energy national labs and NASA labs) and various private profit-making and non-profit organizations.

provide other functions to DoD. Their efforts are generally divided among performing in-house work, contracting out work (and monitoring contractors' efforts), and providing technical advice to program managers and buying commands (a function often referred to as being "smart buyers"). It is very difficult to describe a typical DoD lab because they differ in size, in the mix of these functions, and in a number of other basic elements. However, what they all have in common is that they are owned and run by the government, staffed by government employees, and subject to a large number of laws and regulations. There has been a continuing and, in recent years, rising concern that they are inefficient, ineffective, self-serving and duplicative of industry work, and increasingly hampered in doing their jobs by the conditions of being part of the government.

DoD has some important unique characteristics, but it is not the only large organization that relies heavily on new technology nor the only establishment that runs R&D programs and facilities. Large corporations and the governments of other nations do the same. Their specific goals may not be the same: DoD buys defense equipment to meet a threat, corporations seek to develop and market products in a competitive market, and other nations seek to enhance their economic positions as well as their security. But all share the general goal of marshalling technology assets to achieve some purpose. To some extent, these other entities provide some of the background against which DoD must plan and execute its programs (certainly the evolution of the threat is another). But they also provide potential models of management techniques that might be useful to DoD in solving its management problems.

The technology base programs and laboratories produce technology, but that technology is of no use unless it makes its way into fielded systems that the military can use. There is great concern that it simply takes too long to get new technology into the field. Systems take upwards of 10 years to develop and produce, and when they finally become operational, they often embody technology that is viewed as obsolete, either because better technology exists in the labs or in industry, or because consumers can purchase better technology at their neighborhood stores. In the previous report, OTA found that delays are not a technology base problem: they occur after the technology is developed. However, delays are a major obstacle to keeping our technological lead in fielded equipment.

While a majority of the most visible technology in defense systems comes from DoD and companies that contract with it, a significant part comes from the "nondefense" sector. Mundane technology—like bolts—has often come from industries that sell to both military and civilian customers. And at the subcomponent level, much also comes from the civilian side. Increasingly, these "dual-use industries" are sources of advanced technology, sources from which DoD should be able to draw (and in some cases must draw, because the technology is ahead of what the defense world is building). Increasingly, leading-edge technology is developed in the civilian sector and then finds its way into defense applications. But government rules that make doing business with the government different from selling in the commercial sector create significant barriers to companies moving into government work. Some of these companies are heavily involved in defense work, while others now do little or no business in the defense sector. Moreover, dual-use industries are becoming increasingly internationalized, raising issues of the competitiveness of U.S. firms in the world market and dependence on foreign suppliers in defense procurement.

DoD has become less able to drive the direction of technology. While some areas are pursued primarily for defense applications, others are molded by the consumer market. Large commercial markets generate enormous amounts of capital that fuel research and development. That R&D is primarily directed toward applications and products with large potential commercial payoffs. The relatively small amount of business represented by sales for defense applications is in many cases not significant enough to swing the direction of development. There are still many important areas of development that are primarily, or exclusively, defense-oriented. But the pattern of technology originating in the defense sector and "spinning off" into the commercial sector is being replaced by parallel development and, to use the Japanese term, "spin on" of commercial technology to military applications. Faced with this situation, DoD can buy cutting-edge technology developed in the civilian sector, or it can spend large amounts of money to keep a comparable leading edge resident in-house or with defense contractors.

As a consequence, DoD finds itself (or its contractors) having to buy from companies that do not need its business. Large aerospace companies have to play by DoD's rules: defense is their only business, or at least an overwhelming component of their business. But small, leading-edge technology companies can make much more money in the private sector without the trouble of playing by government rules. They can opt out of doing defense work.

This assessment examines dual-use industries through the mechanism of case studies, concentrating on three industries: advanced composites, fiber optics, and software. These present different perspectives. The advanced composites industry is heavily involved in defense business, but U.S. companies may see their commercial base erode as international competition heats up. Moreover, many of the major companies are international or integrated with foreign firms. U.S. fiber optics producers now sell very little for defense applications. But DoD has important uses for their products. Government buying practices form major barriers to these companies doing business in the defense market, and they are beginning to face stiff competition in the civilian market from foreign competitors. Finally, the software industry is one that straddles both worlds, and moves very rapidly. Software is at the heart of most new defense systems, particularly command, control, communications, and battle management systems.

All of these topics have been the subject of numerous studies, which have produced conflicting conclusions. This report pulls together much of that work, along with original research and analysis. Moreover, while DoD management and industrial/trade issues have been the subject of legislation and proposed legislation, the problems are not yet solved. The next section discusses the major issues before Congress.

## OPTIONS FOR CONGRESS

The U.S. defense effort rests on a strong, broad, dynamic base of research and development. Government and private institutions, and civil and military establishments all contribute. But this defense technology base is also characterized by:

- a heavy burden of government rules, regulations, safeguards, and procedures that stifle the ability of DoD to develop and exploit technology;
- the lack of an effective system for high-level planning and coordination; and
- the lack of a clear government policy and coherent strategy for dealing effectively with dynamic trends in the international high-technology economy.

To those who have followed defense industry, technology, and procurement, none of this will come as a surprise. These problems—and more—have been noted and studied for at least three decades. But despite repeated attempts to fix it, the system has remained resistant to major improvements. Indeed, the major problems have continued to worsen, although probably more slowly than if no measures had been taken.

The U.S. is not faced with a defense technology base that is in deep crisis. The Services and other defense activities fund a great diversity of research and development, run a large number of laboratories that do credible—and often outstanding—work, and successfully exploit that technology and technology developed elsewhere. But the process has a number of serious shortcomings that may be amenable to significant improvement. Moreover, important recent trends threaten to intensify these shortcomings and magnify their importance. U.S. leadership in high-technology industries that are vital to defense is eroding in the face of strong international competition. Budget restrictions predicted both by Congress and by the Administration will reduce funding for technology base activities at a time when the costs of research and development are increasing. And DoD's ability to compete successfully for key technical and managerial personnel is declining.

On top of all this, a heavy burden of rules and regulations impedes the development and exploitation of technology and the successful transition of developments into fielded systems. The accumulated actions of past Congresses are a major contributor to the difficulties. Laws passed for a variety of good reasons, taken together, bog the system down. Lack of clear policy on the part of both Congress and the executive branch impedes the solving of important problems.

Virtually all the easy solutions have been tried. It is unlikely that any fruitful but painless approaches remain. Congress and the executive branch will have to face some hard choices. These include altering institutional arrangements that—despite their deficiencies—have become comfortable, and sacrificing existing goals in order to achieve more efficient development and exploitation of technology.

Based on the analysis in this report, OTA has identified seven basic issues that profoundly affect the welfare of the defense technology base. These are not specific action items, but rather broad agenda items that warrant congressional attention. For each of these there are many different choices as to what individual policy directions to take, and within those, a myriad of measures (and choices among measures) for implementation. Implementation is clearly important, for without any sense of how to implement a policy, it remains simply an abstraction. There are options that can be implemented only through legislation, because today the law forbids them or provides no way to make them happen. And there are options that can be implemented without changing the law—through executive action or changes in DoD's internal regulations. Congress can have a hand in effecting these sorts of changes by making its wishes known or by using its considerable powers of persuasion.

### ISSUE 1: Reforming the Defense Acquisition System

The defense acquisition system is a major contributor to the long delays in getting new technology into the field and erects formidable barriers to exploiting technology developed in the civilian sector. While Congress did not intend the system to be slow, cumbersome, and inefficient, laws passed to foster goals other than efficient procurement have made it so.

The system has weathered many attempts at reform because its problems are rooted in several basic causes. It is dictated in part by our basic system of government which demands checks and balances on the expenditures of large amounts of public funds, provides for a tug and pull between the interests of the executive branch and those of Congress, and permits both branches to reevaluate programs yearly in light of changing factors and interests. But much of the problem can be traced to laws that Congress has enacted to curb abuses and to foster goals other than efficient procurement of defense equipment. Laws and regulations have been added to ensure:

- civilian control over military procurement,
- Administration control over Service activities,

- congressional control,
- protection of congressional constituent interests,
- environmental protection,
- fairness,
- competition,
- accountability,
- honesty,
- controllable business practices,
- minority interests,
- small business interests,
- protection against conflicts of interest, and
- prevention of large profits at taxpayer expense.

These many ends often conflict with each other and with the objective of quick and efficient procurement, which leads to compromises that can satisfy few, if any, completely. Thus, the consequences of achieving these other objectives have included high costs, long procurement times, inefficient production, and restricted access to technology.

To promote these and other goals, the government has developed business practices and criteria that differ markedly from those of the civilian market. Buyer and seller have an adversary relationship; accountability is stressed over efficiency and price; and the government insists on visibility into how its contractors conduct their business. Government imposes restrictions on profits, trade secrets, and accounting procedures that are at variance with typical commercial practices. This discourages many innovative companies from seeking defense business.

History provides little hope that a few clever, relatively painless moves will be sufficient to make the system significantly more efficient while satisfying other goals. **If Congress is serious about making the system work better, it will have to face some hard choices.** One choice is to give efficient procurement greater emphasis over other goals. This would most likely mean that the system would become less fair, less competitive, less accountable, less responsive to minority and small business interests, etc. Another option would be for Congress to give up some of the power it has over major defense programs, or to curtail sharply some of the many centers of power within the executive branch. This would not necessarily make any particular program run better—two layers of management could be just as ineffective as 20—but it would remove major impediments. Instituting multi-year budgeting, which could also make programs run more quickly and smoothly, would likewise require both Congress and the executive branch to give up some power. Finally, Congress could loosen up the rules under which DoD conducts business, allowing business practices to move closer to those of the private sector. But inherent differences between government and private operations will always remain. For example, the government is accountable for the expenditure of public funds and is very sensitive to allegations of misuse. Where a business would be willing to absorb some pilfering if it were exceeded by the cost of prevention, the government is usually willing to spend whatever is necessary to prevent fraud.

Few such moves would come for free. For example, relaxing accountability rules could make it easier for companies to cheat the government. It may well be that, weighing all these factors together, Congress will decide that the current balance among all these interests is proper, and that inefficient defense procurement is an acceptable cost. While concerns for efficient procurement will push in the direction of loosening up the system, a need to respond to a recent history of procurement scandals, failed programs, and high-cost low-quality equipment will likely push in the opposite direction.

### ISSUE 2: Independent Research and Development (IR&D) Recovery

Current law permits companies having contracts with DoD to bill to the government, as a cost of doing business, part of the cost of their internally generated R&D program. Industry generally believes that current rates of recovery are inadequate. Some think recovery rates are too high. DoD cannot seem to present a coherent position. IR&D recovery is not treated in this assessment, but it is very likely to be on the congressional agenda. Interested readers are referred to OTA's previous report *The Defense Technology Base: Introduction and Overview*.[6]

### ISSUE 3: Reforming the DoD Laboratory System

As a whole, the DoD laboratory system performs its function of supporting defense procurement. As a group, laboratory managers are capable and experienced and provide much of the corporate memory for technology base activities. But the system is vast, complicated, and uneven in performance. The structure of the system as a whole—the number, types, sizes, orientations, and institutional connections of the labs—may be restricting their utility and effectiveness. Moreover, the management system under which these government owned and operated facilities are run is rendering it increasingly difficult for them to function effectively. A long list of rules impedes their daily operations and makes them increasingly unable to compete for highly qualified scientists and engineers. In general, Congress can choose to:

- reform the system itself,
- order DoD to reform it according to congressional guidelines, or
- leave the job to DoD.

Whatever course Congress chooses, it is unlikely that the correct approach will be either simple or obvious.

There are three basic approaches to reforming lab management. The least disruptive would be to alter, within the current civil service system, the rules under which they operate. This could include:

- extending the principal features of the NOSC/China Lake personnel experiment to other labs,
- permitting the labs expedited procurement procedures for scientific equipment and services, and
- providing multi-year funding.

Alternatively, Congress could decide that R&D is inherently different from other government activities, and that the labs should be allowed to operate differently from the rest of DoD. This might include permitting salaries for scientists and engineers to rise above current civil service ceilings and allowing the labs to build and modernize facilities by going outside the military construction process. The most radical approach would be to convert some or all of these facilities to government-owned, contractor-operated (GOCO) facilities, like the Energy Department National Laboratories. Conversion to GOCO could solve some of these problems, but would be no panacea.

Congress should also seriously consider altering the overall structure of the laboratory system. This could include closing some labs, consolidating others, shifting the internal make-up and missions of some, and creating new ones. Corporate research labs, like the Naval Research Laboratory, might be established for all the Services; or the in-house capabilities of many labs could be greatly improved. In the process, the system should get simpler, not more complicated. Greater integration of DoD labs with other government labs—reform of the overall government lab system—might also be considered. This could include forming research centers to spearhead major thrusts into areas of particular significance for both defense and commercial needs. These would be drastic steps requiring careful, detailed study and assessment of the individual labs before implementation. If done correctly, they could lead to greatly improved benefits from DoD R&D expendi-

[6]Released March 1988, report No. OTA-ISC-374. Available from the U.S. Government Printing Office, Washington, DC.

tures. If done carelessly, they could be counterproductive. At the heart of the process would be devising a system for evaluating the performance of the laboratories and their component parts. This ought to include the quality of work as well as its relevance to both identified Service needs and potential future advances.

Restructuring the lab system may be a necessary response to budget pressures that reduce funds available to run them. Significant reductions could be accommodated by reducing all efforts proportionately, but this would reduce good work as well as bad. Other approaches are closing the least productive and useful labs or effecting a more extreme restructuring of the entire system to maximize performance and utility at a lower overall level of effort.

### ISSUE 4: Reforming Strategic Planning of Research and Development Programs

Unlike many governments and large corporations, the Department of Defense does not have a central headquarters-level system for planning and coordinating its technology base programs. Planning is carried out by the Services, the defense agencies, and SDIO; coordination among similar projects is done at the laboratory level. This lack of central focus is repeated both higher up the chain—at the overall national level—and within the individual Services.[7] This is not necessarily bad. If centralization stifles unplanned innovation and healthy competition, fails to support Service needs, or results in decisionmaking by the uninformed, then it is counterproductive. However, lack of overall planning can lead to wasteful duplication of efforts, lack of critical mass to solve common problems, fractionated efforts, and inattention to areas that are on no component organization's agenda. It also risks failing to identify areas of common or overarching significance. If there is to be strategic planning and central coordination, it will have to be done by the Office of the Secretary of Defense (OSD). Congress should decide whether—as many DoD studies have advocated—OSD ought to be given greater power (or encouraged to exercise the power the law already gives it) to plan, coordinate, and oversee technology base programs; or whether Service dominance should be supported and reinforced. More forcefully, Congress could order OSD to develop a strategic planning process to lead to a coordinated, department-wide technology base investment strategy.

As currently organized, OSD oversees Service technology base programs at one organizational level, DARPA at a second, and SDIO only at the highest level. This inhibits real coordination. Moreover, it leads to the lack of a high-level advocate within OSD exclusively for technology base programs, lowering the status of technology base programs within both DoD and Congress.

Strategic planning and program coordination are different from central management. The former refers to a strategic OSD planning function providing the ability to orchestrate the entire program. OSD could perform this planning role from a broad perspective over all the technology base activities that the individual Services do not have, but it would lack the detailed information and insight into the workings of specific programs necessary to manage them effectively. Planning and coordinating programs and then letting the extensive Service R&D organizations manage them is different from aggregating similar programs and managing them from OSD.

Congress could also define more clearly what its own role is. It seems unlikely that Congress can provide direction to the thousands of individual projects. Congress could actively involve itself in the strategic planning process or confine its activities to demanding that OSD produce and defend a strategic R&D plan.

[7]The Services seem to exercise more influence over their components than OSD does over the Services.

### ISSUE 5: Reforming Government Personnel Practices

Recruiting and retaining qualified scientists and engineers is a major problem for DoD laboratories. In the current sellers' market, government salaries and benefits for technically trained personnel are not generally competitive with either industry or universities. Many DoD labs have given up trying to recruit the best and the brightest. Loosening up the rigid civil service salary structure is a principal component of ideas to reform lab management, and being able to pay competitively—above civil service ceilings—is a major incentive for converting labs to GOCO status. Federal pay raises, if they are enacted and applied in any significant way to scientists and engineers, could substantially help the situation; alternatively, Congress could consider a separate pay scale for scientists and engineers more in line with industry and academia. This may not be a permanent problem, since the market for scientists and engineers tends to be cyclic. But until such time as it turns around, defense technology base efforts are being hurt by a system that cannot adjust to the market. It is also possible that this time the market will not turn around, that the current expansion in high-technology industry—coupled with demographic trends—will keep the supply short for a long time to come. Congress may also want to consider efforts to increase the number of students in technical disciplines. Defense efforts are particularly hard hit by shortages because they mostly require U.S. citizens and can take little advantage of the large number of foreign graduate students in U.S. universities.[8]

Some observers see similar problems in attracting good managers of acquisition and technology base programs. People with the requisite skills and knowledge can command greater salaries in industry, and are reluctant to work for DoD. "Revolving door" rules are also a disincentive to government service. Congress may wish to consider reviewing salary levels. It may also be worthwhile for Congress to gain deeper insights into the inhibitory effects of other employment restrictions and reconsider them in this light.

### ISSUE 6: Fostering Greater Coordination Between Defense and Civil Research and Development

National defense benefits from a vibrant civilian technology base. Civilian research provides another large source of technology that finds its way into defense systems, and effective civilian R&D underpins a strong economy that provides greater revenues for defense efforts. The ability of the military to achieve and maintain leading-edge technology will, in many cases, depend on the health of corresponding civilian industries. In a very general sense, economic security is a major component of national security; the ability of the United States to compete economically is intertwined with its ability to compete militarily.

The U.S. defense and civil sectors are not isolated from each other, but they are far from closely coupled. Two relatively separate sectors have evolved—one military and the other commercial. The diffusion of civilian technology into defense systems is hampered, as is the availability for commercial purposes of technology developed in the military sector. Some of this is unavoidable: security often demands that some technology be kept under wraps. But much is the result of government business rules that erect barriers to commercial companies selling to DoD and of a weak, high-level technology policy apparatus.

[8]The question of potential shortfalls in the future supply of scientists and engineers is addressed in U.S. Congress, Office of Technology Assessment, *Educating Scientists and Engineers: Grade School to Grad School*, OTA-SET-377 (Washington, DC: U.S. Government Printing Office, June 1988); and U.S. Congress, Office of Technology Assessment, *Higher Education for Scientists and Engineers—Background Paper*, OTA-BP-SET-52 (Washington, DC: U.S. Government Printing Office, March 1989).

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Other industrialized nations—particularly in Western Europe and Japan—construct their technology efforts with a greater emphasis on economic development over military development than does the United States. They are increasingly demanding that military technology support commercial development whenever possible. In Japan, almost all technology is developed for commercial purposes, and some of it is then exploited for military uses. What is appropriate for these other nations is not necessarily good for the United States, since neither Japan nor any Western European nation aspires to be a superpower. However, these are the nations with which the United States is competing economically. We may be able to benefit from making both military and civilian R&D do double duty.

There are several things Congress could do to foster greater symbiosis of civil and military technology. Steps could be taken to expand the availability for commercial exploitation of the vast amount of R&D done in DoD laboratories and under contract to DoD. Tying the Defense laboratories more closely to those of other agencies—for example by fostering exchanges of personnel or forming major research centers for dual-use technology—could benefit both military and civilian developments. Both the development of technology and its transition into engineering could be helped by movement of technical personnel between government and industry.

The acquisition system could be reformed to make it easier for DoD to do business with innovative companies in the commercial high-technology industries. Government regulations on profits, data rights, and accounting procedures all discourage these companies from seeking defense business.

Congress may find it worthwhile to reconsider current mechanisms for setting technology policies at the highest levels of government. In particular, it may wish to provide for a high-level organization that would oversee and coordinate major government-sponsored R&D programs.

### ISSUE 7: Dealing With International Trends in High-Technology Industry

The United States is failing to maintain a competitive commercial base for some technologies that are important for defense procurement. Long standing industrial and trade policies may have to be reformed if the United States is to maintain the industrial capacity necessary to support essential dual-use technologies.

Both Congress and DoD have been concerned about the movement of high-technology industries offshore. This has spawned several responses, including attempts to legislate that DoD buy almost exclusively from domestic suppliers. This approach would probably minimize foreign content in U.S. defense systems, but it attacks the symptom rather than the cause. It would have little effect on the ability of U.S. companies to compete effectively in the international marketplace—a key to having healthy, leading-edge companies here for DoD to buy from.

Having dual-use companies in the United States and available to DoD requires that they be sufficiently competitive on the world market to stay in business. Defense business alone is not usually big enough to keep them afloat. And creating captive companies that exist only on assured DoD business will almost certainly guarantee that technology falls behind the state of the art. Furthermore, cutting ourselves off from foreign technology will mean depriving our defense efforts of important technology that is not available here but possibly is available to the Soviets on the open market.

The United States will have to deal with two fundamental phenomena. First, high technology is a worldwide enterprise. The United States no longer has a monopoly on it. We can change our position relative to the rest of the world, but it is extremely unlikely that we will regain the dominant position the United States once enjoyed. Second, individual companies and entire industries are becoming internationalized. It is becoming increasingly difficult (if not impossible) to define what an American company is. Plants in the United States are owned by foreign nationals or foreign-based corporations. And U.S. companies open plants in other nations. Moreover, international partnerships lead to foreign interests in U.S. ventures and partial U.S. ownership of foreign factories. Protecting U.S. interests and ensuring U.S. sources of supply are therefore not simple matters. This is complicated by the measures that other nations take to protect their companies and their home markets.

The United States has yet to begin to formulate a policy to deal with this situation, both with regard to defense procurement and as it relates to the future of the U.S. economy as a whole. Congress will be faced with decisions on how dependent on foreign sources DoD can be, which high-technology industries must be kept viable in the United States, how to maintain those industries, and how to protect U.S. defense needs as companies become internationalized. Congress will have to formulate policy with regard to foreign ownership of U.S. plants and foreign siting of U.S.-owned facilities—or encourage the Administration to do so.

The solution is almost certain to be found among the choices that lie between the two extremes of buying defense components only from U.S.-based and owned suppliers, and buying solely on the basis of getting the best deal. The former is likely to be incompatible with staying on the leading edge of technology, and the latter may well reduce the U.S. base of technology and manufacturing to a level that is insufficient in time of crisis if not in peacetime. These intermediate choices include buying from:

- U.S.-based foreign-owned companies,
- U.S.-owned companies regardless of location, and
- nearby sources (i.e., Canada or Mexico) regardless of ownership.

In formulating policy, the Nation will have to decide how important foreign ownership is and to what degree domestic siting of development and manufacture is necessary. That policy will have to take into account factors such as: international patterns of trade, manufacturing, and corporate ownership; the costs and opportunities of maintaining domestic capabilities; existing relations with other nations; and the effects of policy choices on foreign relations. It is one thing to be interdependent with an allied nation, and quite another, as the oil shocks of the 1970s demonstrated, to be dependent on just any nation. Every nation ultimately presents a different case, but the spectrum ranges from Canada—which is adjacent, a NATO ally, and defined as part of the North American industrial base—through our European NATO partners, Japan, other European trading partners, and ultimately to nations with which our ties are very uncertain.

The intricacies of formulating policy are illustrated by the problems of trade in defense equipment with our NATO allies. The United States is pursuing multinational cooperation and integration of defense-related development programs through vehicles such as the Nunn Amendment, both for political-military reasons and to promote sales for U.S. defense firms. But these actions will also lead to greater competition from European defense companies in the United States and abroad. Access to European technology will be offset by the diffusion of U.S. technology.

Policy decisions regarding foreign dependence for defense needs fall into the jurisdictions of DoD and the Armed Services Committees. But the broader issue of how the United States should deal with the international economic situation in order to achieve these and other goals will involve a much more diverse cast of players. Congress will have to decide both how it will approach the problem in a manageable way, and what restructuring might be necessary within the executive branch.

## MANAGEMENT OF PROGRAMS AND FACILITIES

The system used by the Department of Defense to run its technology base programs is dominated by two major characteristics that are practically unique among large technology-based organizations. First, the system is inherently decentralized, with planning and management dominated by a bottom-up approach. Second, it relies heavily (although not exclusively) on a large, diverse group of government owned and operated laboratories devoted to defense research.

Planning of technology base programs is done primarily by the Army, Navy, Air Force, DARPA and the other defense agencies, and SDIO.[9] The Office of the Secretary of Defense primarily serves as a monitor and data collector, deferring to these component organizations on matters of program direction. OSD collects budget requests and passes them to Congress; after the funding is approved, the component organizations run their own programs. Within OSD there is a hierarchy of oversight that inhibits rational integration of programs: the Services report at one level, DARPA reports one level up, and SDIO reports only to the Secretary of Defense. While not unique in running its programs this way, DoD follows a minority path. Most organizations exert much more top-down coordination and control over planning and management of technology programs.

The labs owned and run by DoD have two general shortcomings. First, most are not strictly laboratories and lack the multidisciplinary pool of talent necessary to be effective in developing a broad range of modern technology. Although they interact, they are generally independent of each other. Developing technology is not the only (or even the primary) mission of most of these labs, but access to that capability underlies the ability to perform other missions. Second, the government-owned, government-operated (GOGO) management arrangement has created many problems that impair the ability of the labs to function effectively. Other organizations structure their lab systems and lab management differently.

Worldwide, there are three major trends in the planning, management, and performance of technology development: top-down planning; centralized management; and collaboration. Moreover, among the governments of other industrialized nations there is a movement away from concentration on defense research and toward emphasizing civilian research that can be exploited for both economic and defense gains, as well as a movement away from government ownership of laboratories.

### Department of Defense Technology Base Programs

The Department of Defense does not have a centralized system for strategic planning of technology base programs. It has a federated system in which the central authority—the Office of the Under Secretary of Defense for Acquisition—plays an advisory and coordination role, but either lacks or fails to exercise the power to make major decisions. Those decisions are made by the component organizations—the Services, DARPA, and SDIO. The planning process is both top-down and bottom-up, but it is clearly dominated by the bottom-up approach: most real decisions are made within the compo-

[9]In fiscal year 1989 the three Services together will spend 40.2% of the technology base funding (6.1 plus 6.2 plus 6.3A). SDIO will spend 39.3%; DARPA will get 13.8%; and the remaining 6.7% will be spent by the other defense agencies—the Defense Nuclear Agency, the Defense Communication Agency, the Defense Mapping Agency, the Defense Intelligence Agency, the Defense Logistics Agency, and the National Security Agency. Among the agencies, DARPA occupies a special place because of its role as a source of R&D to complement Service programs. Efforts of the other agencies tend to be more specialized.

nent organizations. OSD provides general guidance and reviews Service programs, but does not exercise any strong role in molding them. Attempts by OSD to mold programs (usually to keep to budget ceilings) are often viewed by the Services as uninformed, capricious, and arbitrary. This arrangement generally results in OSD not being able to guide or coordinate the technology base programs. However, OSD has in the past provided leadership for some special cross-Service programs, such as VHSIC, MMIC, SEI, and STARS.[10]

This system is not necessarily bad, but it seems to be ineffective in producing a coherent technology base program. Those who believe OSD ought to provide strong leadership find the current system disappointing. To those who believe that OSD ought not to be controlling technology planning, it is the proper approach, even if OSD occasionally weighs in too heavily and disrupts programs. They believe that the users of technology—the Services—ought to plan and control its development, that giving too much power to OSD risks losing Service support for technology base programs, and that the Services are better able than OSD staff to preserve technology base funding.

Central planning and central management are two separate but related issues. Without top-down planning a program lacks, as DoD's currently does, a broad consistency of purpose and coordination to ensure that important areas are not left unaddressed, and that healthy competition among competing developments does not become wasteful duplication. Central management can help ensure that the results of central planning are carried out, but it can also result in control of programs by those least able to understand them.

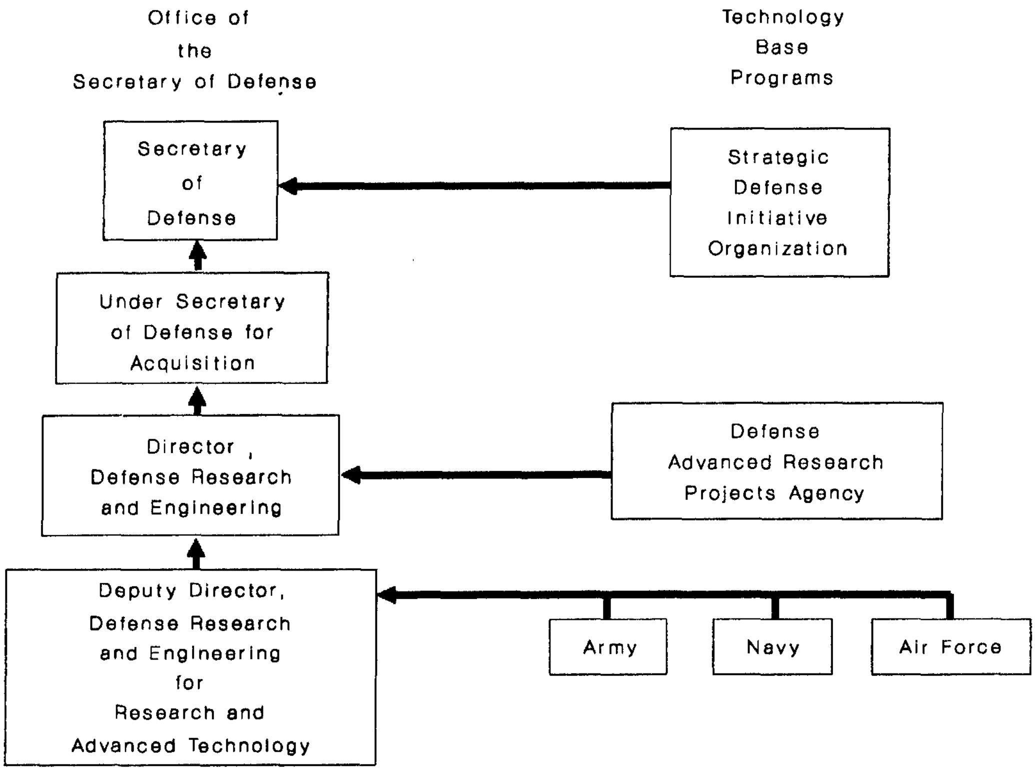
Organizationally, the problems arise from two sources. First, OSD lacks either the ability or the will to exercise power over the Services. And second, there is no one individual or office that serves as a focal point and coordination center for the technology base programs of all the component organizations. This results in diffusing the power to plan and coordinate, and precludes establishing a high-level advocate for technology base programs who is free of competing interests. The Goldwater-Nichols reorganization changed the players and their titles, but did not correct these basic problems.

Within OSD, all technology base programs *with the exception of SDI* are the responsibility of the Undersecretary of Defense for Acquisition. This is shown schematically in figure 1. But the technology base is only one small part of what he is responsible for—he also oversees the rest of research, development, test, and evaluation (RDT&E) as well as all of procurement. DARPA reports directly to the Director of Defense Research and Engineering (DDR&E) for oversight, but oversight for the Army, Navy, and Air Force programs rests one level farther down the chain with the Deputy DDR&E for Research and Advanced Technology. The DDDR&E(R&AT) is the highest ranking official with responsibility only for technology base programs, but he only has responsibility for less than half the technology base. Thus, the Service programs are coordinated at the DDDR&E(R&AT) level, but they are coordinated with DARPA's program one level higher up the chain, and balanced with SDI only at the highest level. This produces a hierarchy of influence among these component organizations and a mismatch that makes it difficult to balance their demands.[11] Moreover, no one with the power to oversee the entire technology base program can be an

[10]Very High Speed Integrated Circuits; Monolithic Microwave Integrated Circuits; Software Engineering Institute; Software Technology for Adaptable, Reliable Systems.

[11]Manufacturing technology programs, vital to ensuring producibility of items, are accorded a generally lower level of oversight and advocacy than product technology programs.

**Figure 1—A Hierarchy of Oversight**




SOURCE: Office of Technology Assessment, 1989.

advocate for it unencumbered by other, possibly conflicting, responsibilities.

Overall goals for technology base programs are supposed to be specified in the annual Defense Guidance document. But in reality, the Defense Guidance devotes little space to the technology base, providing only very general guidance that can be used to justify just about anything the Services, DARPA, and SDIO want to do. The result is that these component organizations plan more or less independently, based on internally generated criteria, and link their plans to the general language of the Defense Guidance. The OSD review of Service plans is predominantly a data-gathering exercise with little real power exerted from OSD. And real coordination is hampered because DARPA and SDIO programs (which together account for over half of the funding) are considered only at higher levels. Thus the Services and agencies dominate the planning process.[12]

It is not the case that the Services do not talk to each other or to DARPA or SDIO. There is considerable coordination among projects having similar technical foci, but this occurs at the project level and not at the overall program level. There is much technical interchange but little programmatic coordination. OSD could

[12]Top level planning is typically not done within the Services either; ideas come up from lower levels. However, in recent years the Services have been conducting high level studies of their future technology needs: Air Force Forecast II; Navy 21; and Strategic Technology for the Army. The Air Force had been planning some of its technology base program around the results of Forecast II.

exert strong influence at this level through its technology reviews, but it only conducts a few such reviews each year.

**Because no single individual or office has responsibility for all technology base activities and only for the technology base, it is difficult to have a strong and consistent advocate for technology base both within the DoD bureaucracy and in relations with Congress and the Office of Management and Budget (OMB).** (This problem is mirrored within the Services with similar results.) Nevertheless, OSD personnel spend a large part of their time defending technology base programs or answering congressional mail, leaving little time available to evaluate technology base programs. It is not surprising, therefore, that OSD and the Services do not have a systematic DoD-wide approach to evaluating technology base activities. Evaluating last year's programs is a key to planning next year's. If OSD personnel do not have the time to evaluate last year's programs, they lack a solid basis on which to judge Service plans for next year.

The structure of the bureaucracy is not the only contributor. The relationships among institutions within DoD also play a major role. The Services and DARPA have traditionally had the upper hand with OSD. SDIO was designed to be able to proceed without interference from OSD or the Services. Typically, this sort of "pecking order" will persist in the absence of positive actions to change it.

Personnel is another factor. Although OTA has encountered OSD staff who are competent, dedicated, and overworked, there is a consensus among experts that, like the labs, OSD suffers from restrictions that limit its ability to get and keep the best people. While experts are divided as to how to solve the problem, most agree that paying more and decreasing career restrictions would help. Some believe that the problems would be best solved by vesting power in a professional staff with long tenure, removing it from the hands of political appointees and other "short timers." Others think that only a constant infusion of "new blood" will help: rearranging the system so that very capable managers could take such jobs for a fixed term (e.g., 4 years) and then return to industry.

## Department of Defense Laboratories

Reports on the shortcomings of DoD laboratories go back at least 30 years. The mind-numbing array of specific issues that these earlier reports have raised can be captured by two fundamental questions:

- Does the DoD have the type and quality of laboratories it needs?
- Are the management arrangements under which these laboratories are run inhibiting their ability to perform as needed?

### Type and Quality of Laboratories

To be precise, DoD has no laboratories. The Army, Navy, and Air Force departments own and operate a large number of research, development, and engineering (RD&E) centers, none of which are laboratories in the pure sense, i.e., institutions solely for conducting research. These centers perform a variety of functions ranging from research through full-scale development to occasional limited-scale manufacture of military equipment items. The mix of activities varies from center to center, with some—such as the Naval Research Laboratory and the Army's Harry Diamond Laboratory—being more heavily oriented toward research than others. As a shorthand, the term "defense laboratories" is used to refer to these government owned and operated RD&E centers.[13]

The structures of the defense laboratories—how big they are, what kind of work they do,

[13]DoD is also supported by contractor owned and operated laboratories such as the John Hopkins University Applied Physics Lab and the MIT Lincoln Lab, and by national laboratories operated by contractors for DOE. For more information on the institutions that support the defense technology base see: *The Defense Technology Base: Introduction and Overview*, OTA-ISC-374 (Washington, DC: U.S. Government Printing Office, March 1988).

etc.—have evolved historically, based in part on the different procurement systems of the three Services and the roles each has seen for its laboratories. These structures are quite different among the labs. However, the management arrangements and modes of operation—which are similar across all of them—are a consequence primarily of law and also of DoD and Service regulations.

Comparing the defense laboratories to other government R&D institutions is difficult because DoD's role as a large purchasing agency makes it almost unique within the government. NASA is perhaps the closest analog because it too purchases products of technology, but it also builds things and conducts research and space exploration. The national laboratories that support the Department of Energy build nuclear weapons and pursue a broad base of research for the furtherance of science. Industry, which also runs laboratories, ultimately builds things.

Comparing DoD labs among themselves is also difficult because no two are really alike. They differ in three distinct dimensions: the subject areas they focus on; the mix among categories of work (6.1, 6.2, etc.); and the weighting of their missions among a number of basic tasks. In addition to conducting research and development, these tasks include:

- buying R&D from contractors and monitoring the contracts;
- advising program offices on responding to proposals from industry to do development and production work (i.e., acting as "smart buyers" of technology);
- providing a base of technical expertise and know-how that can be drawn upon to solve problems as they arise or to follow new areas of technology;
- training young officers in science and engineering;
- solving technology-based problems (or equipment-based problems) encountered by field commands; and
- designing and producing very small numbers of special purpose items needed by field commands.

They also differ in size, source of funding, and the orientations and "cultures" of the organizations they primarily work for.

All of these differences make objective evaluations and comparative ratings of these institutions very difficult to perform. Most evaluations and comparisons appear to be subjective ones, even when performed by highly qualified individuals. For example, Service labs are frequently criticized for not doing top-flight science, especially when compared to national laboratories or major university laboratories; but performing scientific research is not the major mission of these facilities.

Nevertheless, there is a common thread among all the tasks the labs perform: they all require the laboratory to be a center of technical expertise. Most don't *require* the staff to be conducting research and contributing to the advancement of science or technology, but all *benefit* from a staff that has hands-on expertise: a staff member who is contributing to the leading edge is closer to it than one who is simply reading about it, and is more likely to get a seat at the table when the real experts meet.

There are three basic approaches to providing the research core of an R&D facility. The first is to build a large, diverse, multiprogram laboratory with a staff that does research in a broad range of disciplines. The DOE national laboratories fit this description, as do the corporate research centers of several very large corporations such as IBM, AT&T, and General Motors. These labs push forward the frontiers, provide a large pool of talent that can be directed and redirected to solve problems or follow new areas of technology, and provide a base of knowledge from which other labs can draw for more narrow applications. Staffs typically number well over 1,000 and are heavily weighted toward advanced degrees. The Naval Research Lab is the only DoD lab that fits this mold.

A second approach is to build labs with staffs of a few hundred that concentrate their efforts in one or a few areas. Several Army laboratories—Night Vision, Harry Diamond, Electronic Technology & Devices, etc.—are structured this way. These facilities can have programs that are at least as good as those of the multiprogram laboratories in a few selected areas. However, this focus is bought at the cost of loss of breadth and flexibility to respond to a broad range of problems. Moreover, as modern technology becomes more complex, even a single area of concentration can rest on a broad base of underlying disciplines. Size can constrain these laboratories from effectively pursuing their few areas of concentration and from shifting their focus. This problem of lack of critical mass is even more pronounced in the third type, the model followed by most Defense labs: a medium to large RD&E center with small cells of expertise embedded in it. These labs do not have in-house research as a focus, but as a supporting function. Hence the cells of expertise, however skillful and productive, tend to be narrow and thin: in some cases the departure of one or two key individuals could destroy that expertise.

In detail, the Army, Navy, and Air Force run their RD&E centers differently. But in general they all function the same way: technology generated in-house, in other Service labs, externally under contract, and any other place the staff has access to, is assimilated with the aim of transitioning it into the procurement system. The accumulated base of knowledge is used to advise the procurement officers regarding the technical qualities of various proposals to develop and build systems.

**The central question is whether this system has been, and is really capable of, delivering the goods.** Does the technology transit into and out of RD&E centers, and are the staffs up to the job? This is a very complex question requiring an intensive investigation, but it is absolutely key.

If the answer is "yes," Congress ought to stop worrying about the labs and let them get on with their work. Steps might be taken to make their jobs easier by easing management burdens. However, even if the labs are judged to be doing a good job, budget constraints may make it necessary to consider restructuring.

If the answer is "no," there are a number of steps that might be taken to fix things. These range from taking steps to ease management problems (which will be discussed below) to drastic reorganization of the entire system. Some involve centralizing, consolidating, closing, and moving institutions. **However, such steps have far-reaching consequences and can be nearly irreversible. They ought to be taken only after much deliberation.**

One approach would have each RD&E center include or be closely associated with a large multipurpose laboratory, the small cells of expertise being replaced by a large, diverse pool of technical talent. Clearly, doing so for each RD&E center would be prohibitively expensive.

An alternative approach would be to provide each Service, or DoD as a whole, with a central corporate lab and tie the RD&E centers closely to it. The Naval Research Lab might be a model. Smaller labs of more limited scope are a second choice, but because they are inherently less flexible than multiprogram labs, arrangements would have to be made either to shift their focus or close them down as the areas of technological interest shift. As an alternative to building up the research bases within the Services, greater use might be made of DOE national labs as technology bases for the Services. Consolidating facilities either within each Service or across Service lines under OSD could offset the cost of expanding the underlying labs. But this runs the risk of cutting the links of the RD&E centers to their parent buying commands and further restricting the transition of technology into the procurement system. Unless handled carefully, it could also sever the very important links of the labs to the field commands.

**Management Structure of Laboratories**

The problems that plague the Services' government-owned, government-operated laboratories (GOGOs) and the causes thereof have been extensively documented. They are inherent in the laws and regulations that govern the operations of these labs. While these laws and regulations have not changed greatly over decades, the trend within the last few years has been for their application to become more onerous, making the government labs less attractive places to work at a time when the market for technical talent has become much more competitive.

The difficulties fall into three related categories: problems in recruitment and retention; difficulties in conducting the day-to-day business transactions necessary to get the work done; and long delays in updating buildings and major equipment. The latter two are problems in their own right as well as contributors to personnel difficulties. Effective management is also impeded by funding that is often unpredictable and fluctuates from year to year.

Even premier laboratories, like the Naval Research Lab, are having difficulty attracting the best and the brightest. Many of the RD&E centers have all but given up trying: they now recruit from a small circle of mostly local schools and hope to "grow" their own in-house expertise. OTA's observations support the points made in earlier studies:

- most of the labs have difficulty hiring and retaining highly qualified personnel;
- the government is at a major disadvantage in competing with industry and academia; and
- the system makes it difficult to reward good performers, penalize the poor performers, or tie salary closely to performance.

The "NOSC/China Lake Experiment," in which the Navy loosened the salary structure for scientists and engineers at the Naval Ocean Systems Center and the Naval Weapons Center at China Lake, helped with recruiting and retention in the entry and midlevels. Similar novel approaches including salary structure and educational opportunities are under consideration by the Services. But since these do not raise the ceiling on salaries; they do little to solve the problem of attracting and retaining key senior people. Losing senior researchers is a double liability: exceptional senior people do exceptional work, and they also attract younger people, many of whom will accept otherwise less attractive work conditions in order to work with someone special.

Interesting work helps to attract and retain people. Good people stay if the work is challenging, if discretionary funding is available to allow them to "follow their noses," and if they have an opportunity to pursue a technical career without being sidetracked into management. But increasingly, technical people in Service labs can only get ahead if they become managers, and in those management jobs they spend an increasing amount of their time in administrative tasks and insulating their bench-level people from bureaucratic "paperwork" imposed from above.

At most DoD labs the Technical Director has little or no control over the most important support elements of his organization—the personnel office, the general counsel, the procurement office, etc., all of which report to parent commands. And construction of new facilities is handled out of military construction (MILCON) accounts for which the labs usually fight a difficult, and often losing, competition with a long list of other claimants. This results in obsolete facilities.

The Defense Science Board has recommended changing the laws and regulations that are causing the problems, loosening up the system to enable the Defense labs to compete more effectively. While this might be helpful, it would require a long list of changes in both legislation and government regulations. This involved agenda could be very difficult to complete. However, a congressional decision to treat the laboratories differently from other government offices might facilitate the changes.

An alternative would be to convert the labs to government-owned, contractor-operated, or even to contractor owned and operated (COCO) facilities. This would seem an easy way out of the morass of government red tape. GOCOs do have greater management flexibility in personnel management, but the evidence for greater flexibility is ambiguous in areas other than personnel. GOCOs can pay higher salaries, can hire and fire more easily, and have much greater flexibility in rewarding good work and shifting personnel. They also display greater flexibility in shifting the focus of their work, and have some advantages—although not so dramatic—over GOGOs in their ability to purchase equipment and facilities.

DOE GOCOs appear to show a greater aggressiveness in seeking out and developing technology. And, at least in the design and manufacture of nuclear weapons, transition of technology into applications is more direct than it typically is in DoD. But this is not necessarily a consequence of their being GOCOs. Size, full-spectrum stance, and research-oriented culture are all contributors. So is the relationship that has evolved between DOE and its labs: the missions of the labs have been construed in a very broad way, facilitating changes in program directions as technology evolves.

While there are some real advantages to converting to contractor operation, there are some important offsetting factors. No government-funded institution can escape oversight merely by converting to contractor operation. Funds derive from congressional appropriations, and Congress holds senior officials of sponsoring agencies accountable for their use. Thus, the tendency is for the government to impose on its contractor laboratories many of the same rules and regulations it lives under. Consequently, with time GOCO labs tend to become more like government-operated laboratories. Government rules under which the sponsoring agencies operate tend to be passed down to the contractors, so the GOCOs are not free of the majority of government impediments. Government policy appears to be that even though government regulations do not apply to GOCOs, GOCO practices ought to be consistent with them. OTA found that the perception of "red tape" and the burden of bureaucratic paperwork reaching down almost to the bench level was no different at GOGOs, GOCOs, and COCOs.

Although there have been many studies of government labs since the 1962 Bell Report, none have questioned its finding that there are "certain functions which should under no circumstances be contracted out. The management and control of the Federal research and development effort must be firmly in the hands of full-time government officials clearly responsible to the President and Congress."[14] There are some functions that are inherently governmental: passing them off to contractors would raise major questions. For example, being a smart buyer and advising a program office on the technical merits of proposals is probably not a responsibility that ought ultimately to be entrusted to a contractor, although today contractors are part of that process.

One advantage of government labs—and a major function—is that they can respond immediately to problems that emerge in the field. Staff can be ordered to stop whatever they are doing and turn their attention to the problem at hand. This would be more difficult for contrac-

[14]*Report to the President on Government Contracting for Research and Development*, reprinted in W.R. Nelson (ed.), *The Politics of Science* (New York, NY: Oxford University Press, 1968), p. 200.

tors to do, unless the contract had been carefully crafted to allow for the contingency.[15] At several contractor operated facilities OTA was told that response times would have to be measured in months, if not years.

While all DoD labs could benefit from fewer restrictions, not all are equal candidates for conversion to GOCO status. Those that conduct in-house R&D would be better candidates than those that function primarily as "smart buyers." Similarly, those that cannot solve their management problems within the government system would be more likely candidates for conversion than those whose managers believe they can.

### Other Approaches

After examining a number of approaches used by other organizations to manage technology programs, some basic themes emerge that may be applicable to DoD management of its technology base programs and laboratories. First, in most governments and companies, R&D policy is approved at the upper levels of management and promulgated throughout the organization. Second, centralized control over research projects is the rule. It is supported by frequent reviews and combined with a readiness to cut losses when projects do not pan out and to buy technology outside the organization if that appears to be a more economic approach. Third, both public and private organizations are moving toward collaboration as a means of affording research of the magnitude dictated by modern technology. Finally, on a broader note, the Europeans appear to be moving toward the Japanese point of view that technology efforts ought to be focused on enhancing the economy: a strong high-tech economy will produce both more money available for defense and "spin-on" of technology for defense purposes.

For at least two decades the Europeans have been worried about their economic positions, particularly relative to the United States. But the emergence of Japan and other Asian nations as economic powers has greatly intensified their concerns. This has spurred efforts to integrate the European Community (EC), notably the movement to a "single Europe" in 1992. Moreover, as their fears of economic problems have increased, their anxiety over Soviet military power has receded. Hence the mood is to reduce the drain on the economy of defense oriented R&D, while increasing substantially research oriented toward civilian products. The Europeans are looking for ways to make defense R&D support civil production; defense labs are increasingly viewed as national assets that can be used to help make civilian industries productive. The trend appears to be to do research and exploratory development (the equivalent of 6.1 and 6.2) predominantly in civilian-oriented labs. Only in the advanced development stage would the work take on a more military-oriented cast. The prevailing philosophy appears to be that science and technology policy should be integrated whenever possible with economic and industrial policies. In this regard, the Europeans are moving away from the U.S. model and toward the Japanese model.

It is tempting to take the attitude that if our system has significant shortcomings we ought to adopt someone else's. But this approach is fraught with peril. While there are important lessons to be learned—and these general themes appear to be worth considering—it is not necessarily true that DoD can simply adopt some other system as its own. All organizations are different, and they do not all see themselves as solving the same problems. Management approaches tend to be rooted in corporate "culture" at least as much as they are the result of dispassionate analysis. It is somewhat dangerous to adopt the attitude that what works for some other organization ought to work for DoD. For example, the sheer scope and size of DoD's technology base activities dwarfs nearly every

[15] For example, level of effort support contracts.

other organization examined, and might even rival the aggregate of them. Furthermore, it is not clear that other organizations are significantly more successful than DoD is in developing and nurturing technology and using it to good effect. The success story everyone immmediately turns to is Japan. But Americans are not, and do not behave like, Japanese. And the Japanese seek to use technology somewhat differently than does DoD.

**Planning and Priorities**

In contrast to DoD, in which a laissez-faire approach and "bottom-up" planning predominates, most Western European governments set national civil and military R&D objectives from the top. Working through central committees or advisory panels, cabinet-level officials set priorities and ensure that the goals are translated into specific programs in either government or private laboratories. The technical experts are usually left free to determine the composition of the specific programs, but they must be able to justify program relevance to higher authorities. In addition, the European Community is exerting an increasing top-down influence on the member nations' research programs. Exploiting allies' work and avoiding duplication of effort is a growing theme. The Japanese approach is perhaps less formal, emphasizing government/industry consensus building and the role of industry, but ultimately major decisions are made by a central body.

Industry generally follows a somewhat similar centralized approach. Major corporations typically have central procedures for establishing business objectives, including identifying the key technologies that are expected to contribute. Once these selections are made, the component companies are free to decide how to pursue them. But corporate oversight typically remains continuous and close.

There has been strong criticism that U.S. defense R&D focuses too much on the near term, both in government and in the private sector. European companies are even more likely than U.S. companies to spend their R&D money for near-term applications. This trend has become more pronounced recently in both Europe and the United States as technology base expenditures have declined as a proportion of defense spending. In contrast, however, budgets for long-term research—particularly civil research—are increasing for many European countries and for the EC. This is tied to a perceived linkage between R&D, economic competitiveness, and prosperity. Governments are seeking to improve their industries' competitive positions by making civil research the driver and blurring the distinction between civil and military R&D. The Europeans' short-term focus and declining funding in defense research appears to be offset by a longer term focus and more generous funding for civil research. In Japan, the government role is greatest in long-term developments for which the risks are high and the payoffs not evident.

Growing fear of Japanese and U.S. industrial competition has fostered European interest in large-scale, centrally directed technological initiatives. These have been largely multinational in nature, such as ESPRIT, EUREKA, RACE, and BRITE,[16] although there have been single nation programs such as the U.K. Alvey program. These are modeled, in part, after a succession of U.S. initiatives—beginning with the Manhattan project—that, while not always successful, propelled technology forward. Large collaborative efforts are also employed by the Japanese, but their efforts tend to have more industry funding and less government money.

A similar approach currently in favor in Europe and to an increasing extent within U.S. industry is to employ special research teams, or "centers of excellence," often in collaboration

[16]European Strategic Program for Research in Information Technology (ESPRIT); European Research Coordinating Agency (EUREKA); Research and Development in Advanced Communications for Europe (RACE); Basic Research into Industry Technology for Europe (BRITE).

with universities or potential competitors. These groups concentrate on technologies where a large critical mass of personnel and other resources, or interdisciplinary research, is considered essential. U.S. examples are SEMATECH, the Electric Power Research Institute, Semiconductor Research Cooperative, and the Microelectronics and Computer Technology Corp.

### Management and Control

European governments not only plan their R&D programs centrally, they also manage the execution of those programs centrally. Large companies also tend to keep tight central control. In both cases, the trend is also toward centralized control of laboratories in an attempt to establish the optimum balance between generic research and product-oriented (or mission-oriented) research.

DoD's laboratory system is basically mission-oriented, with most laboratories dedicated to specific warfare specialties. Mission focus provides a closer link between technology and military applications, but it also encourages duplication in facilities, resources, and projects. European labs and programs are increasingly organized along technology, not mission lines. In France, Germany, and the United Kingdom the defense research activites are planned, organized, and managed by central authorities independent of service requirements and development activities. Centrally managed civil research programs are generally oriented around generic technologies. Similarly, EC programs are directed toward enabling technologies, with applications left to industry.

DoD's extensive network of government owned and operated laboratories is unique among Western defense establishments. With the exception of the United Kingdom, European governments own few, if any defense labs, and the British are in the midst of drastically consolidating their laboratory system. However, there are many more European government-owned and government-sponsored laboratories doing civil research.

Industry is generally moving in two directions. Most R&D is being moved out to the component companies. Some corporate research centers are being pruned back or even closed. As money gets tight, it is easy to view corporate research centers as expensive luxuries—"money sinks"—rather than as investments. But at the same time corporations are establishing corporate level centers of excellence in key technologies (or forming collaborative efforts in them). Technology is transferred to the product divisions, at least in part, by assigning personnel from the product divisions to temporary jobs in the central facilities and then moving them back to use and disseminate the technology they studied and helped develop. Industry is also moving in the direction of collaborative research, sharing the escalating costs of modern technology. This research is of necessity technology oriented, not mission oriented.

### Collaboration, Coordination, and Technology Transfer

Collaboration in research is now a way of life. High costs and worldwide competitive pressures are forcing governments and industries to pool their resources. Collaborative projects play a central role in Japanese R&D. European governments and industries explored cooperative research in the 1970s and early 1980s, but in the mid 1980s growing concern that they were falling behind the United States and Japan led to a series of serious collaborative measures. Moreover, the European members of NATO, after more than 20 years of ad hoc collaboration on defense and other aerospace projects, are now working on establishing a coherent, systematic program of collaboration. Breaking down the long-standing barriers that have isolated European companies from each other and fragmented markets is an explicit objective of recent high-technology collaborative initiatives. In addition, European companies see that they each have to draw on a broader base of technology than was necessary in the past. Recognition that Germany's strong position in world trade is due, at least in part, to a collegial, collaborative relationship between industry, academia, and government also helped spur interest in collaboration.

U.S. companies are not only engaging in collaborative programs at home, they are also joining with European (and Japanese) companies in various ventures.

**Applications: Transitioning Technology From Lab to Products**

DoD has been criticized both for leaving technology in the lab too long, resulting in obsolete weapons, and for rushing it prematurely into production—which creates unreliable products. Neither allegation is without foundation. Technology transition is one of the most difficult problems of development. European governments and industries appear to be no better at technology transition than DoD is. Japan appears to have a unique success at transitioning technology rapidly and effectively from the lab into production. The Europeans appear to be studying and beginning to apply the Japanese experience. Teams of researchers, designers, engineers, manufacturing specialists, and even marketers are being brought together early in the life of a product in order to perform in parallel what usually gets done sequentially. The parallel development of process (manufacturing) technology and product technology is considered a particularly important factor.

Examples of the close relationship that is essential between research staff and those who develop specifications exist in all successful companies; but in large and diverse government organizations the liaison and communication that is required may be jeopardized by interdepartmental rivalries and parochialism which only strong management and direction can dispel. In DoD, requirements for new systems are set by the Service buying commands, and development is done by industry. These are obliged by law to stay at arms length; the government labs provide the primary link between them—and the labs are not always successful.

## GETTING TECHNOLOGY INTO THE FIELD

Government officials and others have expressed concern and frustration over the age of technology in fielded U.S. systems, particularly those just beginning to roll off assembly lines. Comparisons usually take two forms. First, government and industry researchers have laboratory developments that are clearly superior to what is going into the field. Second, dual-use technology in defense systems often lags significantly behind what is available in the consumer markets, and by the time a system has been in the field for 5 to 10 years it can seem outdated compared to what Ford or Radio Shack is selling.

Technology in production will always lag behind technology in the lab. Taking developments off the bench, engineering them into real systems, and getting those systems into production is a time-consuming process for military and civilian manufacturers, as well as for movie producers, think tanks, book publishers, and many other enterprises. Indeed, very little legislation moves instantaneously from brain storm to law. Major military systems are generally much more complicated than civilian products, and hence the product cycles are much longer.[17] In addition, the process of getting approval to begin a military project is generally considerably longer than the equivalent process in the consumer sector. Furthermore, military systems have long lives, and dealing with frequent updates is a logistical nightmare, so it is not surprising that changes occur much less fre-

[17]In commercial products, complexity is usually the enemy, something to be managed carefully.

quently than the typical yearly changes in consumer products. It appears to make sense to change the current model Toyota because of a relatively small change in engine technology. (Indeed, it helps sales to tell consumers that this year's model is "all new" and "innovative," and technology is often changed just to enhance marketing.) But it makes absolutely no sense to rebuild the entire fleet of tanks every year to take similar changes into account. The problems of maintaining different equipment types in the field mean that decisions to update part of the total inventory, while often made, are not taken lightly. Finally, DoD is not in the business of developing and fielding technology for technology's sake; its job is to get better capabilities into the field in a reasonable time at a reasonable cost. Up to a point, it is not unreasonable to argue that new technology ought to buy its way onto a system.

Military-specific technology is usually the pacing technology for entire systems, determining the schedule for getting the system into the field and controlling the rate at which the dual-use technologies in the system get fielded. The entire acquisition system is geared to the pace set by these military technologies. It is often the case that after a system design is frozen, the commercial counterparts of technology embedded in it continue to move forward, sometimes dramatically, resulting in several generations of products before the military system is produced. This produces military systems that are not as advanced as some commercial products; but if responding to rapid changes in dual-use technology were to prevent freezing the design of a system long enough to get it into production, none of the technology would ever get produced.

Thus, while it can be misleading to compare fielded military technology to laboratory technology or selected consumer technology, it is important to ask whether new technology can get more quickly and more effectively into the field. (It is also legitimate to ask why the military cannot have the same products—like radios, CRT displays, trucks, and clothing—that consumers can go out and buy.)

The problem of getting new technology into the field is not that the United States is unable to develop new technologies with military relevance. It is rather a problem of the transition of that technology into engineering, the time needed to begin manufacture, and the rate at which new systems are built. It can be improved in three general areas: improving the **insertion** of new technology into acquisition programs (i.e., the transition from technology base to engineering and production); improving the **acquisition** process that engineers and produces systems; and improving the **affordability** of systems so that they can be bought more rapidly.

### Technology Insertion

The technology development and system acquisition processes are largely (but certainly not completely) separate. Technology base work takes place in a variety of institutions, including some companies that ultimately build systems. Engineering and production are done in private companies (not always the same ones that did the technology base work) under the supervision of DoD program managers. This causes a major bottleneck at the point at which technology moves from technology base to acquisition. Several mechanisms exist to bridge this gap: general technical interchanges between Service lab people and industry; IR&D and contract research that involve some companies in a development; involvement of lab people with the program offices (part of the "smart buyer role"); and formalized Service transition programs.

Many studies of the transition issue seem to agree that nonsystem-specific prototyping, pursued with 6.3A funds, presents the greatest opportunity to improve technology insertion. It has the potential to solve two problems. By demonstrating feasibility, these advanced technology demonstrations help reduce the high risk carried by some technical developments. And they help correct overoptimism by demonstrating the limitations in the current state of the art. Overoptimism leads to promising too much, which in turn leads to disappointing systems and to lengthy and costly redesign efforts. The new emphasis within DARPA on prototyping is apparently an attempt to ease the transition into system design of technology developed under DARPA programs. DARPA has always been the focus of technology that does not fit neatly into what the Services want to do. However, if the Services do not take DARPA seriously, it is not at all clear that DARPA's prototyping effort will have any use.

### Acquisition

In searching for the causes of delays, the acquisition process has been the primary candidate. Even when the system is working smoothly it seems to take a long time to move programs through; but it usually is not working smoothly. And when it bogs down, delays lead to further delays through escalating costs, compensatory stretch outs, and time-consuming attempts to fix any particular program's specific problems. While the consensus is that the system is in trouble, it has weathered study after study without apparent improvement.

Several studies have found that acquisition (advanced development, full-scale development, and production) takes longer than it used to. But the data are not all that clear: there is certainly no obvious trend toward rapidly increasing times. It does take longer in the 1980s than it did in the 1950s or 1960s, but there is not enough data to discern clear trends over the past decade. Studies of fighter aircraft procurement, the most-studied system type, conclude that whatever increases have occurred are in the front-end decision process and in production, not in full-scale engineering development. Data on other systems are less conclusive.

It is generally held that commercial industry completes programs more rapidly than does DoD, but there are significant differences between government and industry that make it possible for industry to avoid many of the basic problems that plague DoD acquisition. These basic problems are "built into the system," they are consequences of the characteristics of U.S. Government. For example, canceling a program that has grown too much in cost or schedule to be profitable is easier than canceling one that, despite schedule slippages and cost overruns, is judged essential for national security.

But enhancing national security is not the Nation's only goal. Goals like fairness, environmental protection, equal opportunity, jobs, and competition all figure into how both Congress and the Administration judge defense procurement programs. DoD itself has goals it must pursue in addition to managing programs efficiently: maintaining the defense industrial base, ensuring that the most efficient producer does not drive the others out of business (contrary to what industry would do), etc. Government is not solely concerned that a program provide the best capability at the lowest cost most quickly. Moreover, the political process in both branches of government—the tug and pull over resources and goals—introduces uncertainty into programs, even when Congress and high-level executive offices do not micromanage programs.

The structure of the DoD acquisition system is much more cumbersome than that of private sector companies. That structure is, in part, determined by government's size and unique role. DoD program managers are accountable to five or six layers of bureaucracy up to the Secretary of Defense. These layers typically have extensive horizontal structure, so the program manager (PM) has to satisfy a large number of people, many of whom have power over his or her program but no responsibility for it. To complicate matters further, the PM reports up one chain for oversight of the program, and up another for the planning, programming, and budgeting system which is responsible for determining the funding for the program. But this involvement of the OSD bureaucracy, as well as that of OMB and Congress, is part of the checks and balances on the expenditures of billions of dollars.

While industry shares many of DoD's problems, it has a very strong incentive to manage successfully: failure could mean bankruptcy. In many instances industry works under a simpler system involving a direct link between the program manager and a high company official having the authority to make decisions, settle disputes, and insulate the PM from external pressures. The PM has responsibility for the program: if it fails it is his fault and his job may be at stake. The DoD PM typically has to obtain several levels of approval for any action; there are many people who, in trying to ensure that the PM does not fail spectacularly, will also prevent him or her from succeeding spectacularly.

Several factors are major contributors to delays in programs: the sequential processes of requirements generation, resource allocation, and system selection; program variability (or instability) caused by many players making changes; bureaucratic paralysis; inappropriate organization for defense procurement; and the quality and incentive structure for procurement personnel. Underlying these are the basic structure of the government, the nature of the bureaucracy, the organization of the DoD procurement system, and the conservative risk-averse nature of government organizations.

Requirements generation and resource allocation involve the Services, OSD, OMB, and ultimately Congress. They are highly political, which often leads to overpromising in order to get program approval. Overpromising leads to cost growth and schedule slippage. But the system makes it easier to readjust the program to these realities rather than to go back and question the requirements that produced them in the first place.

Constant changes in defense acquisition programs are commonplace, leading to cost increases and schedule slippages. Variability results from the requirements process, the risks inherent in new technology, the political/budgetary process, and personnel turnover. While the disruptions caused by these factors can be somewhat controlled, the underlying causes cannot be eliminated.

Baselining—a form of contract between program managers and their Services—was developed to limit changes in programs. But making baselining work requires giving program managers more authority over their programs than they now have. Neither program managers nor Services can control budgets or other changes and conditions imposed by OSD, OMB, and Congress. Moreover, external factors that affect a program—like threat, doctrine, and resources—will cause changes in the program no matter how well it is managed.

However, Congress, OSD, and OMB can decide to limit their direct involvement in a program (or Congress can decide for the others). But, at least in the case of Congress, this would involve giving up power which it jealously guards. Congress has already agreed, in principle, to relax oversight for a few major acquisition programs, which would require reauthorization only at significant milestones rather than annually. As yet, none of these milestone authorizations have been submitted to, or approved by, Congress. Not all members are likely to agree that efficient functioning of defense acquisition programs is more important than other issues they are concerned with, including the (possibly shifting) interests of their constituents. The budget process specified by the 1974 Budget and Impoundment Control Act and Public Law 99-177 (Gramm-Rudman-Hollings) increases Congress' incentives to keep control of as many budget items as possible so that it can engineer the budget levels it agrees to.

Perhaps the most discussed problem is the bureaucratic burden individuals and companies must struggle through in order to do their jobs. A 1977 Defense Science Board (DSB) panel concluded that increases in acquisition times are all bureaucratic: "it does not take any longer to do something, it just takes longer to obtain the necessary approvals and acquire funding . . . ." The program manager's job has become increasingly complicated, accompanied by lengthening time to complete contracting actions and increased regulation, oversight, and auditing of contractors. The overall perception is that of increasing regulatory and bureaucratic burden, but studies have found the picture to be unclear. While some indicators of burden have been clearly increasing, others have remained the same or declined. Moreover, measuring the effects of regulatory and bureaucratic activity is even more difficult than measuring the activity itself. For example, estimates of the added costs due to regulations and bureaucracy range from 5 to 200 percent!

This "red tape" is unambiguously greater in government than it is in private industry. What in industry can be a straightforward, one-step, project initiation process involving the manager and a high corporate officer is in DoD a two-step process involving the PM, a committee within DoD,[18] and Congress. Both the DSB and the Packard Commission recommended bringing the system closer to an industrial model in this regard, and the Goldwater-Nichols Act tried to implement that.

Since the bureaucratic burden arises in part from government attempts to have programs satisfy goals other than getting the job done most efficiently, solutions can be of two types: those that try to streamline the system without changing its mix of goals; and those that seek to change the balance among goals, particularly the balance between having an efficient and successful program and satisfying all the other government goals. One suggested solution is to review all the regulations to determine whether each is still necessary and whether the aggregate could be streamlined somehow, a daunting task in its own right. Another suggestion is to shift the burden of proof from the PM to those who would slow down the project, making the PM innocent until proven guilty. For example, a competition advocate would have to show that the program was insufficiently competitive or that taking measures to enhance competition was important enough under the circumstances to warrant tampering with the program. But some higher authority would have to be responsible for balancing these claims against the interests of the PM who would always be served by ignoring them.

Some DoD programs do better than most: "black" programs (so it is said), and other special high-priority programs. This success is due in part to their high-priority which affords them high-level attention. Clearly, all DoD programs could not be treated that way or the system would overload. These programs also get special exemptions from various regulations. Granting similar exemptions to all programs would nullify the regulations, defeating the purposes for which they exist.

There has been widespread concern about the process that produces PMs and their chief assistants. These people are either military officers or civil servants. In 1986 the average tenure of PMs was about 2 years. This makes it difficult to give them real power over programs that run many times that long, and creates incentives for them to sacrifice long-term performance in order to look good on their watch. The military personnel usually, but not always, rotate rapidly in and out of the jobs in 2 to 3 years. They do not always have prior experience or relevant training. Many of the civil servants

[18]The Defense Acquisition Board, and perhaps others.

do not rotate, and "remain for so long that they resist innovation and change."[19]

### Affordability

One of the major contributors to delays in getting new technology into the field is the cost of modern development and procurement programs and the resultant program stretchouts and low buy rates. Almost all important systems cost enough to get close scrutiny by OSD and Congress. The battles are fought each year. The result is often that the funding requested by the program is reduced (in some cases dramatically), which slows the development pace and slips the date at which production is initiated.

Once the program is in production, DoD's tendency is to reduce the funding below what had been projected, in order to keep as many programs alive as possible. This leads to buying fewer of any particular item per year, which has two major consequences. First, obviously the slower the rate at which a system is bought the longer it will take to get the capability into the field. It may not delay Initial Operating Capability, but it will certainly delay the date at which a significant capability is fielded. Second, providing insufficient funds to procure at planned rates raises the unit costs, which further decreases the number that can be bought per year.

## DUAL-USE INDUSTRIES

Most of the technology that is engineered into defense systems is still developed in the "defense world" of DoD's laboratories and contractors. This is particularly true of the exotic technologies that are the centerpieces of advanced designs. But increasingly, building those systems depends on developments that take place in the civilian sector, a civilian sector that is driven by the international marketplace. This was dramatically illustrated by events during the first week of November 1988. A company called Avtex, which manufactured rayon fibers for the apparel industry, announced that it was shutting its doors in response to foreign competition in the clothing business. This sent shock-waves through DoD and NASA when it was discovered that Avtex was the only producer of fibers that were critical to the production of missiles and rockets. While other sources could be qualified, and other fibers might be found to substitute for the rayon that Avtex made, that process would take longer than the period of time the available supply of rayon would support production. Negotiations were soon completed to keep Avtex open.

High-technology industries are becoming increasingly internationalized: foreign companies and multinationals are technology drivers. Large international markets generate huge amounts of capital that fuel research and development into new products and underlying technologies. The defense components of these markets are often small, giving DoD little or no leverage over the directions developments will take. DoD has to choose between playing a follower role, or spending large amounts of money to keep a competitive leading edge capability in defense laboratories and industries. But because of the cost of developing modern technology, it seems unlikely that DoD can afford to develop all the technology it needs in parallel with the civilian sector. Dependence on the private sector is not all bad: commercial development of technology is a basic strength of the industrialized, non-communist world. Failure to exploit developments in the civilian sector would be throwing away a major advantage over the Soviets. But relying on the private sector means that defense development and production will depend increasingly on the health of the civilian sector and on the ability of DoD and its contractors to gain access to the products of the civilian sector. Thus DoD faces two challenges: maintaining access to the technology developed

[19] J. Ronald Fox and James L. Field, *The Defense Management Challenge: Weapons Acquisition* (Boston, MA: Harvard Business School Press, 1988), p. 312.

in the commercial sector, and coping with the international nature of that sector.

DoD and Congress face three generic problems. The first is keeping dual-use companies interested in doing defense work. Some are leaving the defense business. Others have technology that DoD could use, but are reluctant to get into the defense business. These attitudes are based primarily on perceptions of the difficulties of doing business with the government, and the problems of doing business in both sectors simultaneously. Second, high-technology industries are moving offshore due to foreign competition. Some have almost vanished, others are on the way. Furthermore, it seems likely that in the future some new technology-based industries will develop in other nations and never take root here. Careful balance will be necessary to nurture U.S. industries while maintaining access to foreign technology. Congress will have to consider U.S. trade and industry policy carefully. Third, entire industries, individual companies, and the many-stepped trails that lead from raw materials to finished components cross many national borders. In many cases, it is nearly impossible to determine what a U.S. company is, while in others it is difficult to separate U.S. companies from their foreign partners. Congress will have to come to grips with the meaning of foreign ownership and foreign siting for the availability of technology, as well as with how dependent the United States can afford to be on foreign sources. These international relationships will complicate attempts to protect U.S. supply sources.

### Barriers Between Civilian and Military Industry

Since World War II, the U.S. economy has evolved relatively separate military and commercial sectors. They have different business practices, one dictated by government regulations and procurement practices and the other flowing from the marketplace. In recent years the *international* market has had a considerable effect on shaping the latter.

Government practices have made it increasingly difficult for DoD to obtain state-of-the-art technology in areas where civilian industries are leading, making defense business unattractive to innovative companies and contributing to traditional suppliers leaving the defense business. Many firms that are not heavily involved in defense business are reluctant to deal with the government because they consider it to be a bad customer. Moreover, many do not need DoD's business and can simply opt out. The barriers are not technological, but legal, institutional, and administrative. Some are the direct result of legislation, others flow from DoD regulations, including overly cautious interpretations of laws. Some commercial firms cite excessive regulation, burdensome auditing and reporting requirements, compromise of trade secrets, and loss of data rights. Large defense companies have similar complaints, but have adjusted to working under these conditions. But for smaller companies, getting into the defense business means heavy investment and reorientation of business practices.

A company can organize to do business in either sector, but can rarely do both under one administrative roof. Companies that do business in both sectors typically have separate divisions that are organized differently and almost never share staff, production and research facilities, data, and accounting procedures. These differences are profound. In large aerospace companies the commercial side responds to market conditions, whereas the military side responds to Service programs, government regulations, and the Federal budget. Their planning is "slaved" to the Federal planning and budgeting cycle. Corporate structures and rules tend to mirror those of DoD and tend to pass government encumbrances down to lower level suppliers. Companies doing government contract work have to keep their books in formats that are compatible with government auditing rules and procedures.

Following these and other government rules adds to the costs of doing business, costs that can legitimately be passed on to the government customer. Tighter control of the defense business ultimately translates into higher costs to DoD. The United States is apparently willing to bear this increased cost as the price of other benefits—for example, knowledge that the government is trying to keep the process honest. However, imposing the same rules on dual-use industries has other, farther-reaching effects. It makes them reluctant to do business with DoD and encumbers their products with additional costs that may adversely affect their international competitive positions. When dealing in both sectors, companies can accept either the higher cost of following government business procedures, or the higher costs of maintaining two separate business practices—one for government business and one for other business. With some exceptions, DoD product specifications are also seen as encumbrances; characteristics that are of no value in the commercial marketplace are engineered into the products for sale to DoD.

Government contracts regulate profits, creating a business environment very different from that in which most high-technology companies deal. These companies are used to investing heavily in R&D, recovering their investments through large profits, and then reinvesting in the next generation of product. Moreover, their customers see only the product, whereas DoD insists on knowing how the product was made. Defense contractors get by on small profits, in part because much of their R&D costs are covered either by contract or IR&D recovery. But dual-use companies qualify for little if any IR&D recovery and are reluctant to do contract R&D. The government owns the rights to data generated by contract R&D so that it can keep the subsequent phases of a project competitive by making a data package available to all bidders. But companies that live by their innovation in the commercial market see this process as offering their trade secrets to the competition. DoD procedures provide the winner of a development contract poor profit margins, no guarantee of a continuing relationship with DoD, and little incentive to innovate and provide a superior product.

Some industries, like advanced composites, are currently so closely tied to the defense business that they are apparently willing to live with these problems. But they worry that their competitive position may be damaged as the commercial market develops. At the other extreme, the companies that produce fiber optics are reluctant to get involved in a defense market they see as always being a small part of their business: they do not necessarily see the potential payoff as worth the aggravation.

While the small amount of military fiber optics business might be seen as evidence that the industry is not really important to defense, some within the DoD see it as a critical new technology for future systems, one in which defense could gain tremendously just by exploiting what has been and is being developed in the commercial sector. But DoD has been generally slow in adopting fiber optic technology. Program managers have much to lose by inserting risky new technologies which may delay schedules and increase costs, but little to gain because the advantages of the substitution will usually become apparent only on someone else's watch.

In the software industry, the divergence between government and commercial practices has been enough to produce separate defense and commercial businesses that often do not share technology. The procedures, policies, and management of large-scale systems in the military and civilian sectors diverge starting with requirements definition, continuing in the development or acquisition of software, and throughout the entire life cycle of the software. This restricts the flow of leading-edge technology from defense into the commercial sector and reduces DoD access to readily available commercial products. Most of the differences can be attributed to the policies, regulations, standards, and directives mandated by DoD. DoD software requirements are more rigid than their commercial counterparts. Defense systems tend to be overwhelmingly custom built, while commercial systems will use as much off-the-shelf technology as possible. Software companies are particularly concerned about data rights, which they see as critical to competitiveness. Companies are reluctant to deal under DoD restictions; in their eyes the government would be taking and possibly giving to their competitors the very basis of their business.

### International Competitiveness and the Health of U.S. Industries

The Department of Defense has been concerned for some time about the implications for defense of deteriorating competitive positions of U.S. manufacturing companies in the international market.[20] The government is also concerned from a wider perspective that this trend is weakening and undermining the U.S. economy. DoD shares the concern that a weakening economy and a drain of resources into purchases of foreign goods will reduce money available to produce defense equipment, but its primary concern is the continuing availability of necessary items and technology.

The government does not as yet have a policy regarding dependence on foreign sources for defense material and technology, let alone a game plan for implementing such a policy. The Undersecretary of Defense for Acquisition has recommended a plan to bolster defense-related manufacturing in the United States.[21] The report detailing that plan does not make a statement on how much foreign dependence is tolerable, although it does imply that some is unavoidable.

The complexity of the problem is illustrated by the issue of cooperative development and production of defense equipment with the European NATO Allies. It has been long-standing U.S. policy to encourage multinational procurement of similar defense equipment to foster commonality, to get the best equipment into the forces of all the Allies, to save money, and recently, to exploit a broad multinational technology base. In recent years the Defense Department has made great progress in generating international memoranda of understanding for joint development, with the help of initiatives like the Nunn Amendment. But as the Europeans have become more interested in cooperative developments, they have also sought a greater share in generating the technology and a larger market share for their defense industries. Interest by U.S. companies in joint ventures with Europeans has been spurred, in part, by fears that several trends in European thinking could sharply curtail their sales in Europe. Thus, the cooperative programs are a two-edged sword helping U.S. sales in Europe while stimulating European sales to the United States; and helping U.S. defense policy in general, while both helping and hindering the maintenance of the U.S. defense industrial technology base. Crafting a workable policy will be a tricky job.

There are three basic policy choices:

- demand that anything that goes into defense equipment be built in the U.S. from U.S.-sourced components, taking whatever measures are necessary to ensure that all

[20]For examples, see Defense Science Board, "Report of the Defense Science Board Task Force on Defense Semiconductor Dependency," prepared for the Office of the Under Secretary of Defense for Acquisition, February 1987; Report to the Secretary of Defense by the Under Secretary for Acquisition, "Bolstering Defense Industrial Competitiveness: Preserving Our Heritage, the Industrial Base, Securing Our Future" (Washington, DC: Department of Defense, 1988); and Martin Libicki, *Industrial Strength Defense: A Disquisition on Manufacturing, Surge, and War* (Washington, DC: National Defense University, 1986). See also, U.S. Congress, Office of Technology Assessment, *Paying the Bill: Manufacturing and America's Trade Deficit*, OTA-ITE-390 (Springfield, VA: National Technical Information Service, June 1988).

[21]See "Bolstering Defense Industrial Competitiveness," op. cit., footnote 12.

the necessary industries are alive and well in the United States;

- let the market dictate which industries will be healthy in the United States and look only for the best deals wherever they can be found worldwide; or
- choose some industries that have to be located in the United States, take appropriate measures to ensure that, and let the rest go with the market.

The first and third require some sort of intervention in the international economy, either supporting the international competitiveness of U.S. companies or protecting, supporting, and subsidizing U.S. companies that cannot otherwise survive. Another approach is to design nothing into U.S. defense systems that cannot be domestically sourced. But this cuts off a great deal of modern technology, a Western strength. In making these choices, the United States will have to decide how dependent we can afford to be, and how much independence we are willing to pay for. If the United States demands self-sufficiency without taking measures to keep U.S. companies alive and competitive, the list of technologies available for defense systems is likely to decrease as time goes on.

It will be necessary to decide how to treat dependence on various nations. There are significant differences in being dependent on Canada (already defined as part of the North American industrial base), Britain, our other NATO allies, Mexico, Japan, Korea, etc. U.S. and Canadian companies are closely intertwined. Despite the recent controversy over the trade agreement and other arguments, we are each other's largest trading partners. Canada is also a NATO ally with a common security interest. The chances of being cut off from Canadian sources either by policy or by hostile act are minimal. We are also close to our European Allies; much of our defense equipment is bought to defend them. But we are separated from Europe by an ocean, and they have not always supported U.S. military actions. Other nations are much less tightly tied to the United States.

The high-technology economy is an international one and responds to international market forces. These forces are likely to continue to move industries offshore despite U.S. efforts to will (or legislate) them to stay. In the vast majority of cases, defense business is far too small to provide the necessary clout, particularly when faced with other nations that manipulate their civilian markets to keep their companies healthy. Competition comes from Japan, the smaller Asian nations—Korea, Taiwan, Singapore, etc.—and Western Europe. The Europeans are taking dramatic steps to improve their international competitive position, particularly in high technology industries. These include the economic integration of the EC in 1992, and the funding and encouragement of large cooperative R&D projects.

Although all industries are different, the plight of the fiber optics industry is illustrative. While healthy in the United States, it faces increasingly stiff competition at home and continuing difficulties abroad stemming from limited access to foreign markets. Both the Europeans and the Japanese are making major pushes in fiber optics and photonics in general. U.S. technology and production costs are at least competitive. But while U.S. producers have been largely excluded from some important foreign markets, the U.S. market remains open to foreign vendors. Japanese companies can sell in foreign markets at low prices because their government has discouraged foreign competition in Japan where prices are kept artificially high. The closed domestic market supports overseas competitiveness.

The U.S. software industry faces a different sort of challenge. It is currently strong and competitive, but the rapid growth in worldwide demand for software threatens to outstrip the capacity of U.S. firms to meet it, leaving a large opening for foreign firms to penetrate the market. Japan, France, the United Kingdom, Korea, Singapore, Taiwan, and India have the capacity to penetrate the global market. And many of these nations have trade policies that either discourage sales by U.S. companies or fail to protect the intellectual property rights of those companies: "pirated" software is becoming a major problem. Moreover, the Japanese are making rapid strides in turning software design from art to manufacture, building software factories to increase productivity dramatically.

### Internationalization of Industries

Efforts to protect and nurture U.S. companies will be complicated by trends toward internationalization in high-technology industries. Examples are found in the advanced composites industry in which many of the firms that appear to be American—because they have American names or U.S. facilities—are actually owned by foreign companies and in the fiber optics business where international joint ventures are used to get into otherwise closed markets. International ownership, vertical and horizontal integration, and international siting make it difficult to define in any convincing way what an American company is. Moreover, the sequence of steps that leads to a final product often crosses international boundaries many times and shifts as prices and availability of components shifts. Is a Pontiac built in Korea any more or less an American product than a Honda made in the United States or a Chevrolet/Toyota assembled in California from U.S. and Japanese parts?

Difficulties in identifying U.S. companies will produce difficulties in writing legislation to protect them or establishing DoD policy to encourage the growth of important domestic industries. Foreign plants owned by U.S companies, U.S. plants owned by foreign companies, joint ownership, and joint ventures all offer different sets of problems.

### Formulating Policy

These trends toward internationalization will complicate difficult issues that Congress and the Administration are already facing. Paramount among these is to decide whether the U.S. Government will play a major role in encouraging and supporting U.S. commercial business and industry, or whether—almost unique among the governments of major nations—it will continue to remain more or less aloof, confining its activities to a few international trade negotiations. Other governments encourage the development of commercial technology and associated industry, help to foster a domestic situation conducive to growth, and support aggressive overseas marketing.

Having decided government's role, the next issue would be to define goals. These might include:

- keeping key nondefense manufacture and development in the United States,
- keeping manufacture and development in the hands of U.S.-based (or U.S.-owned) companies;
- preserving some portion of the U.S. market for U.S.-based (or U.S.-owned) companies; and
- gaining access to foreign markets for U.S. firms.

Defining such goals will entail arriving at a working definition of a U.S. company, or at least of how location and ownership affect U.S. national security interests.

It would be necessary to decide how large a role defense needs would play in deciding which industries are in need of government attention. This decision would have to balance the problems of foreign dependence against the risk of diminished access to foreign technology and manufacture. It would also have to consider how much the United States is willing to pay to buy domestically that which may be available at a lower price elsewhere. The lessons of "lowpriced oil" from the Persian Gulf are instructive here. Determining the acceptable degree of offshore dependence for defense equipment will necessitate deciding the level of componentry which DoD would have to specify as coming from domestic sources. For example, is it sufficient to require that systems or subsystems be domestically sourced, or does DoD have to assure that some or all of the components are made in the U.S.A.? This decision would dictate the level at which DoD would need visibility into the manufacturing process and have to keep a data base on suppliers.

Whatever the goals are, Congress will have to decide what levers can be pulled to make those attainable. In most cases, simply controlling defense procurement will not be enough to influence the industry: it may ultimately lead to an inefficient, backward, protected industry that is incapable of competing on the world market. Such an industry might only be capable of providing DoD with obsolete technology or overpriced products. The government has the option of getting more deeply involved in stimulating the development of technology for commercial ends, including making government R&D facilities more available and providing greater incentives for corporate investment. Yet another option is to formulate a strategy—as Japan and other nations have—for controlling access to critical U.S. commercial markets in order to preserve and support domestic industrial capabilities. A third policy lever that can be manipulated, but not totally controlled, is the cost and availability of capital for conducting R&D. Major technological developments are capital intensive, with costs measured in the hundreds of millions to billions of dollars. European and Japanese companies pay less to borrow money than do U.S. companies—far less in the case of the Japanese. This allows them to carry on more projects simultaneously, and to sell the resultant products at lower prices than those of their U.S. competitors, putting U.S. companies at a competitive disadvantage.

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